

## DESCRIPTION

### SPEAKER

#### Technical Field

The present invention relates to speakers and particularly to a speaker that emits sound waves by vibrating a diaphragm. Examples of such a speaker are a dynamic speaker and an electromagnetic speaker, each of which includes a voice coil.

#### Background Art

Fig. 10 is a perspective view showing an example of a conventional speaker unit. A speaker unit 1 includes a cabinet 2. A woofer (low frequency speaker) 3, a tweeter (high frequency speaker) 4, a midrange speaker 5, and the like are attached to a front panel of the cabinet 2. Diaphragms of the respective speakers 3, 4, and 5 vibrate to produce sound waves of corresponding frequencies.

For example, as shown in Fig. 11, the woofer 3 includes a conical diaphragm 6. A voice coil (not shown) causes the diaphragm 6 to vibrate back and forth. The inside bottom of the diaphragm 6 is connected via a damper 7 to a frame 8, while the large-diameter end of the diaphragm 6 is connected via a cone edge 9 to the frame 8. A duct 10 extends inwardly from the front panel of the cabinet 2. In the cabinet 2, the woofer 3 is attached to the duct 10 (see Patent Document 1).

In this speaker unit 1, the vibrations of the diaphragm 6 of the woofer 3 vibrate air in the duct 10, cause the duct 10 to resonate, and allow low frequency sounds enhanced by the resonance of the duct 10 to be reproduced through an opening of the duct 10.

Patent Document 1: Japanese Unexamined Patent Application  
Publication No. 2002-232984

## Disclosure of Invention

### Problems to be Solved by the Invention

However, such a conventional speaker has problems in that the diameter thereof has to be large enough to reproduce low frequency sounds, and that the resonance of the duct causes sound distortion.

Accordingly, a main object of the present invention is to provide a small-diameter speaker capable of reproducing low frequency sounds that are free of distortion.

### Means for Solving the Problems

In an aspect, a speaker of the present invention is characterized in that it includes a diaphragm configured to vibrate in a direction crossing a surface, thereby emitting sound waves in the vibration direction of the diaphragm; and at least one wall member arranged on a sound-wave emission side of the diaphragm, wherein the wall member and the diaphragm are secured to each other, and the wall member vibrates along with the vibration of the diaphragm.

In such a speaker, it is preferable that the inner surface of the wall member be formed substantially parallel to the vibration direction of the diaphragm.

The wall member can be arranged in the shape of a frame surrounding the sound-wave emission side of the diaphragm.

Moreover, the wall member can be formed to have a cross-sectional shape that is substantially the same as the rim shape of the sound-wave emission surface of the diaphragm.

Moreover, the plurality of wall members can be arranged concentrically with respect to the center of the diaphragm.

It is preferable that the height of the wall member be made substantially the same as the maximum amplitude of the diaphragm.

In another aspect, a speaker of the present invention is characterized in that it includes a diaphragm configured to vibrate in

a direction crossing a surface, thereby emitting sound waves in the vibration direction of the diaphragm; and a plurality of tubular elements touching and arranged side by side on a sound-wave emission side of the diaphragm, the tubular elements each having an inner surface parallel to the vibration direction of the diaphragm, wherein the tubular elements and the diaphragm are secured to each other, and the tubular elements vibrate along with the vibration of the diaphragm.

In such a speaker, it is preferable that the height of the tubular elements is made substantially the same as the maximum amplitude of the diaphragm.

The present inventor has found, as a principle of sound production (generation), that the vibrations of a diaphragm do not directly produce sound waves, but initially cause air over a sound-wave emission surface of the diaphragm to be momentarily compressed and then immediately released at once, in other words, expanded (exploded), and the resulting shock propagates and is perceived as sound. Therefore, a speaker of the present invention has a structure in which a wall member secured to a sound-wave emission side of a diaphragm vibrates along with the diaphragm. Thus, the speaker prevents leakage of air compressed by the vibrations of the diaphragm from the sound-wave emission surface (front surface) to the side of the diaphragm. This allows air with a compression rate according to the amount of vibrations (amplitude) of the diaphragm to be efficiently released to the sound-wave emission surface side (forward), thereby allowing low frequency sounds to be efficiently emitted even if the diameter of the diaphragm is small. In addition to low frequency sounds, midrange and high frequency sounds can also be emitted efficiently. Since the wall member is not designed for resonance, the wall member does not have to be as high as the length of a resonance duct. The wall member is high enough if it is substantially as high as the maximum amplitude of the diaphragm. Therefore, the wall member causes no sound distortion due

to resonance or the like, and allows reproduction of high quality sound faithful to the original source.

As described above, the wall member that vibrates along with the diaphragm is arranged on the sound-wave emission side of the diaphragm to prevent air compressed by the diaphragm from leaking from the sound-wave emission surface to the side of the diaphragm.

It is preferable that the wall member be formed in the shape of a frame surrounding the sound-wave emission surface of the diaphragm so as to prevent air captured on the sound-wave emission surface of the diaphragm from leaking.

In particular, if the wall member has a cross-sectional shape that is substantially the same as the rim shape of the sound-wave emission surface of the diaphragm, air over the entire surface of the diaphragm can be captured.

In addition to the wall member on the rim of the diaphragm, a plurality of wall members may be provided to divide the inner part of the rim into a plurality of sections. For example, a plurality of wall members, each having a cross section similar to the rim of the diaphragm in shape, can be arranged concentrically with respect to the center of the diaphragm.

As described above, dividing the sound-wave emission side of the diaphragm into a plurality of sections reduces the area of a section surrounded by each wall member. Since this prevents air leakage and allows air to be held inside the wall members, more accurate sound reproduction can be achieved. Moreover, since the wall members serve as ribs and improve the stiffness of the diaphragm, deformation such as surface waviness can be prevented and thus, the reproduction of sounds faithful to the original source can be achieved.

It is preferable in such a speaker that the height of the wall member be made substantially the same as the maximum amplitude of the diaphragm so as to prevent air compressed by the vibration of the

diaphragm from escaping from the sound-wave emission surface.

To divide the sound-wave emission side of the diaphragm into a plurality of section, a honeycomb wall member composed of a plurality of tubular elements touching side by side may be arranged on the sound-wave emission surface of the diaphragm.

It is also preferable in such a speaker that the height of the tubular elements be made substantially the same as the maximum amplitude of the diaphragm so as to prevent air compressed by the vibration of the diaphragm from escaping from the sound-wave emission surface.

#### Advantageous Effect of the Invention

The present invention provides a speaker capable of reproducing sounds of all frequencies ranging from low to high frequencies faithfully to input signals, and in particular capable of reproducing low frequency sounds even with a small diameter.

The above and further objects, features, and advantages of the present invention will become more apparent from the following description of the best mode for carrying out the invention with reference to the attached drawings.

#### Brief Description of the Drawings

Fig. 1 is a perspective view showing an example of a speaker unit that includes a speaker of the present invention.

Fig. 2 illustrates the structure of the speaker unit shown in Fig. 1.

Fig. 3 illustrates a diaphragm and a wall member of the speaker included in the speaker unit shown in Fig. 2.

Fig. 4 illustrates the relationship between the vibration of the diaphragm shown in Fig. 3 and the compression of air.

Fig. 5 illustrates the relationship between the vibration of a

conventional diaphragm and the compression of air, for the purpose of comparison with the present invention.

Fig. 6 illustrates another example of a diaphragm and wall members of a speaker according to the present invention.

Fig. 7 illustrates the structure of the speaker including the diaphragm and wall members shown in Fig. 6.

Fig. 8 is a plan view showing still another example of a wall member included in the speaker of the present invention.

Fig. 9 illustrates the diaphragm with the wall member shown in Fig. 8.

Fig. 10 is a perspective view showing an example of a speaker unit including a conventional speaker.

Fig. 11 illustrates an example of a conventional speaker included in Fig. 10.

#### Reference Numerals

20	speaker unit
30	speaker
40	frame
42	diaphragm
44	cone edge
50	cap
54	wall member

#### Best Mode for Carrying Out the Invention

Fig. 1 is a perspective view showing an example of a speaker unit including a speaker of the present invention. A speaker unit 20 includes a cabinet 22 that is in the shape of, for example, a rectangular box. A surface 22a of the cabinet 22 has an opening that is, for example, circular in shape.

As shown in Fig. 2, a speaker 30 is attached, toward the opening,

to the inside of the cabinet 22. The speaker 30 has a permanent magnet 32 attached at one end to the inside bottom of a yoke 34. The yoke 34 is made of magnetic material and surrounds the permanent magnet 32. The yoke 34 has a circular hole 36 at the other end of the permanent magnet 32. A columnar center pole 38 attached to the other end of the permanent magnet 32 extends inside the hole 36 of the yoke 34, thereby creating an annular gap between the yoke 34 and the center pole 38. This structure allows a magnetic field to be applied to the annular gap between the yoke 34 and the center pole 38.

A tapered frame 40 is attached to the outside of the yoke 34 around the hole 36. A diaphragm 42 is disposed inside the frame 40. The diaphragm 42 is made of paper or the like and is conical in shape. The small-diameter end of the diaphragm 42 is fitted in the gap between the yoke 34 and the center pole 38. The large-diameter end of the diaphragm 42 is connected to a curved cone edge 44. An end of the cone edge 44 is sandwiched and secured between an end of the frame 40 and a gasket 46. Moreover, a midsection on the outside of the diaphragm 42 is connected via a damper 48 to the frame 40. A central "through" portion of the diaphragm 42 is covered with a cap 50 that is, for example, partially spherical in shape.

In the gap between the yoke 34 and the center pole 38, a voice coil 52 is secured to the diaphragm 42. Audio signals inputted to the voice coil 52 cause the diaphragm 42 to vibrate in a direction orthogonal to a plane covering the large-diameter end connected to the cone edge 44. Moreover, as shown in Fig. 3, a frame-like wall member 54 having a cross-sectional shape that is the same as the shape of the rim of the diaphragm 42 is attached to the large-diameter end of the diaphragm 42, that is, to the rim of the diaphragm 42. When the diaphragm 42 is conical in shape as shown in Fig. 3, the wall member 54 having a circular cylindrical shape is attached to the diaphragm 42.

The wall member 54 is formed such that at least the inner surface

thereof is parallel to the direction in which the diaphragm 42 vibrates. In addition, the wall member 54 is formed such that the height thereof from the diaphragm 42 is substantially the same as the maximum amplitude of the diaphragm 42. It is preferable that the wall member 54 be made of light and durable material. The wall member 54 can be made of the same material as that of the diaphragm 42. Examples of the material for the wall member 54 include, but are not limited to, paper, resin, rubber, wood, and metal. One end of the circular cylindrical wall member 54 is secured to the rim of the diaphragm 42. The rim of the frame 40 of the speaker 30 is attached to the opening in the surface 22a of the cabinet 22.

In the speaker unit 20, audio signals inputted to the voice coil 52 cause the diaphragm 42 to vibrate in a direction crossing the surface 22a of the cabinet 22, and sound waves are emitted in the vibration direction of the diaphragm 42. As shown in Fig. 4, when the diaphragm 42 moves with the wall member 54 to the sound-wave emission side, that is, in the forward direction, air in front of the diaphragm 42 is compressed and then released from the opening side of the wall member 54. The resulting shock propagates and is perceived as sound. When the vibration of the diaphragm 42 causes air to be compressed as described above, the wall member 54 on the rim of the diaphragm 42 prevents the compressed air from leaking from the front to the side of the diaphragm 42, as indicated by dotted arrows in Fig. 4. Therefore, air in front of the diaphragm 42 is reliably captured, compressed, and efficiently released forward. A speaker that is capable of reproducing sounds of all frequencies ranging from low to high frequencies faithfully to input signals, and in particular capable of reproducing low frequency sounds even with a small diameter can thus be provided.

On the other hand, if the diaphragm 42 has no wall member on the rim, air compressed by the vibration of the diaphragm 42 leaks from



the front to the side of the diaphragm 42, as indicated by solid arrows in Fig. 5. In this case, since air in front of the diaphragm 42 cannot be efficiently compressed and the diaphragm 42 has to have a large diameter and provide a longer airflow distance to reproduce low frequency sounds, reproduction of sounds faithful to input signals cannot be achieved.

In the conventional speaker unit 1 shown in Fig. 11, the duct 10 is provided forward of the woofer 3. However, since the diaphragm 6 of the woofer 3 and the duct 10 are not secured to each other, a gap between the diaphragm 6 and the duct 10 allows air to leak therefrom. Therefore, it is not possible to achieve effects similar to those achieved by the speaker 30 having the diaphragm 42 provided with the wall member 54. Moreover, the duct 10 is provided for resonance purposes to produce low frequency sounds, and thus has a problem in that the resonance causes sound distortion. On the other hand, the speaker 30 of the present invention reproduces sounds without distortion, since the wall member 54 having substantially the same height as the maximum amplitude of the diaphragm 42 produces no resonance. Even if the height of the wall member 54 is less than the maximum amplitude of the diaphragm 42, it is still possible to prevent the leakage of compressed air from the front to the side of the diaphragm 42. However, to capture all the air in front of the diaphragm 42, it is preferable that the height of the wall member 54 be substantially the same as the maximum amplitude of the diaphragm 42. To capture all the air in front of the diaphragm 42, the height of the wall member 54 can exceed the maximum amplitude of the diaphragm 42 to the extent that the wall member 54 does not limited to the vibrations of the diaphragm 42.

As shown in Fig. 6 and Fig. 7, a plurality of wall members 54, each having a cross-sectional shape similar to the shape of the rim of the diaphragm 42, may be arranged to provide a plurality of sections.

These wall members 54 are arranged concentrically with respect to the center of the diaphragm 42, and formed such that every wall member 54 has substantially the same height as the maximum amplitude of the diaphragm 42. If the height of the wall members 54 is equal to the maximum moving distance of the diaphragm and when the diaphragm 42 vibrates, air can be reliably captured, compressed, and then released.

The diaphragm 42 provided with these wall members 54 interferes with the smooth flow of air captured when the diaphragm 42 vibrates, since the area of a section surrounded by each of the wall members 54 is smaller than the case where a single wall member 54 is provided only on the rim of the diaphragm 42. Therefore, it is possible to compress and release all the air in front of the diaphragm 42, and reproduce sounds without distortion. Moreover, the wall members 54 on a surface of the diaphragm 42 serve as ribs and improve the stiffness of the diaphragm 42. The diaphragm 42 thus becomes resistant to deformation, such as surface waviness, and the reproduction of sounds faithful to the original source can be achieved.

To similarly reduce the area of each surrounded section while serving as ribs, the wall member 54 may be composed of tubular elements touching side by side. As shown in Fig. 8 and Fig. 9, the wall member 54 may have a honeycomb structure in which hexagonal tubes touch side by side. This wall member 54 is also formed such that the height thereof is substantially the same as the maximum amplitude of the diaphragm 42. The wall member 54 is disposed between the rim of the diaphragm 42 and the cap 50. The shape of each tubular element is not limited to a hexagonal shape, but may be a rectangular shape, a circular shape, or the like.

As described above, the diaphragm 42 provided with the wall member 54 increases the efficiency of air compression when the diaphragm 42 vibrates, and allows the speaker 30 to reproduce low frequency sounds without distortion even if the speaker 30 has the diaphragm 42 with a

small diameter.

Although it is preferable that the wall member and the rim of the diaphragm be equal in shape, the effects of the present invention can be achieved even if the diaphragm with a circular rim is provided with the wall member having a rectangular shape or other shape.

It is preferable that the inside of the wall member be parallel to the direction in which the diaphragm vibrates. However, the inside of the wall member may cross the vibration direction of the diaphragm, in other words, may be directed slightly inward.

The present invention is applicable not only to a speaker having a conical diaphragm, but also to a speaker having a diaphragm with a modified shape, such as a bell-shaped diaphragm that gradually extends in a sound-wave emission direction. In this case, the wall member is attached to the end portion of the diaphragm. The end portion of the diaphragm is a surface substantially orthogonal to the vibration direction of the diaphragm. When the wall member is substantially parallel to the vibration direction of the diaphragm, the surface at the end of the diaphragm is substantially orthogonal to the wall member. Again, the wall member may be directed slightly inward, in other words, toward the center of the speaker such that the wall member crosses the vibration direction of the diaphragm.

The present invention is applicable not only to a speaker having a conical diaphragm, but also to a speaker having a flat diaphragm. Although the wall member shown in Fig. 8 and Fig. 9 is formed on the diaphragm surface around the cap, the wall member can be formed on the entire surface of the flat diaphragm.

The shape of the flat diaphragm is not limited to a circular shape, but may be a rectangular shape or the like. When the flat diaphragm is rectangular in shape, the wall member on the rim of the diaphragm is formed in the shape of a rectangular tube so as to fit the shape of the diaphragm. When the wall members are rectangular tubes that are

similar in shape, the wall members are arranged concentrically with respect to the center of the diaphragm. As described above, when a wall member is to be provided on the rim of the diaphragm or when a plurality of wall members is to be arranged concentrically, each wall member is formed in the shape of a tube having a cross section that is equal or similar in shape to the rim of the diaphragm. Such wall members are applicable to any speaker having a diaphragm that vibrates in a direction crossing a flat surface.